Portable Fuel-Cell-Powered System with Ultrasonic Atomization of H_2O By-product

U.S. Patent Application of:

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Background and Summary of the Invention

The present application relates to low-power portable fuel cells.

Background: Fuel Cells

A fuel cell is an electrochemical power source which is very attractive for many applications. A fuel cell may be regarded as a type of battery, but is significantly different from most common battery chemistries.

All batteries derive energy from a chemical reaction of some sort. In a fuel cell, the chemical reaction is the oxidation of a gaseous or liquid fuel (typically hydrogen), which may be supplied from an external supply. Thus, fuel cells can avoid the lifetime constraints of primary (non-rechargeable) batteries while also avoiding the degradation due to recharging and discharging which affects most rechargeable battery chemistries. The chemical reactions used in fuel cells are relatively energetic, and thus the amount of energy per unit weight is relatively high.

Much of the work on fuel cells has been directed towards larger fuel cells, in the range of a kilowatt to tens of kilowatts or more. However, the high energy density of fuel cell chemistries also makes them attractive for many portable applications, in which the energy requirements are far smaller. In particular, the development of gel-stabilized fuel cell technologies has made fuel cells much more attractive for portable applications. In such applications, the requirements of user convenience and comfort are crucial.

The oxidation of hydrogen produces water. Methanol and other hydrocarbon fuels have been proposed for fuel cells, but

oxidation of any hydrocarbon fuel will produce water (as well as carbon dioxide, which is gaseous and not a problem). A fuel cell will also produce some heat, and some of the water produced will be water vapor rather than liquid water. However, some of the water vapor will condense as liquid water (either in the fuel cell plumbing, or shortly afterwards as the exhaust vapor cools). Thus liquid water will be generated.

The generation of liquid water is a significant problem: users do not want a computer which drips on their paperwork. The total flow of water is very small - on the order of one drop per minute, for 50W of power - but this is enough to be a serious nuisance in some applications.

Figure 1 shows a typical small fuel cell for portable applications. This cell is supplied with air and hydrogen. A container **100** holds a proton transport membrane **102**. The transport membrane 102 can be, for example, a sulfonated styrene/ethylene/butylene-styrene triblock copolymer from DAIS. The membrane 102 is flanked by a porous cathode **104** and a porous anode **106**. (These are made of a porous conductive material, e.g. carbon fibers.) Hydrogen, supplied to fuel manifold **110** through inlet **114**, is catalytically ionized at the interface between anode 106 and membrane 102. Hydrogen can then be transported through membrane 102 as protons (hydrogen ions). Similarly, oxygen is introduced through inlet **116** into oxidant manifold **112**, and is absorbed at the interface between membrane 102 and cathode 104, to form oxygen ions within membrane 102. The oxygen ions and protons react to form water, which is exuded into the oxidant manifold. Typically an excess of air is pumped into inlet 116, so the exhaust port **118** carries air which is only partly deoxygenated, as well as moisture from the reaction. The free energy from the reaction can be extracted electrically at terminals **V+** and **V–**. The voltage per cell will be in the neighborhood of .6V to 1.1V,

depending on load characteristics and cell design.

The drawing of Figure 1 is highly simplified. Since the membrane 102 generates only a small current per square inch, the membrane is typically folded back and forth many times. Thus the manifolds 110 and 112 will typically be long meandering passages, where condensed water can easily block gas flow. Additional pressure is therefore applied to the inputs occasionally, to produce a puff at the exhaust port which vents excess water.

Additional background on fuel cell technology can be found in Kordesh and Simader, FUEL CELLS AND THEIR APPLICATIONS (1996); the HANDBOOK OF BATTERIES AND FUEL CELLS (ed. Linden 1984); in the proceedings of the Grove Fuel Cell Symposia; and in the proceedings of the Annual Battery Conference on Applications and Advances; all of which are hereby incorporated by reference.

<u>Innovative Portable Fuel Cell System</u>

The present invention provides a portable fuel cell-powered system in which the water by-product is disposed of by ultrasonic vaporization. Users will object to the presence of liquid water (or to the presence of steam), but ultrasonic vaporization provides a very convenient way to expel H_2O without the difficulties of handling liquid water in an office environment. Preferably a piezoelectric element is used to vaporize the water by-product, and a small port is used to eject the vapor thus produced.

In one class of embodiments, a heated airstream is combined with the water vapor exhaust port to reduce the chances of liquid water accumulating.

In another class of embodiments, the water byproduct is transported as a very-low-volume liquid flow to a vaporization orifice on the exterior of the system, where an ultrasonic transducer atomizes and expels the water.

Brief Description of the Drawing

The disclosed inventions will be described with reference to the accompanying drawings, which show important sample embodiments of the invention and which are incorporated in the specification hereof by reference, wherein:

Figure 1 shows a typical small fuel cell for portable applications.

Figure 2 shows fuel cells and water discharge path in a first class of embodiments.

Figure 3 shows fuel cells and water discharge path in a second class of embodiments.

Figure 4 shows a block diagram of a portable computer system according to the presently preferred embodiment.

Detailed Description of the Preferred Embodiments

The numerous innovative teachings of the present application will be described with particular reference to the presently preferred embodiment. However, it should be understood that this class of embodiments provides only a few examples of the many advantageous uses of the innovative teachings herein. In general, statements made in the specification of the present application do not necessarily delimit <u>any</u> of the various claimed inventions. Moreover, some statements may apply to some inventive features but not to others.

Figure 2 shows a fuel cell and its water discharge path in a first class of embodiments. Fuel cell **210** is supplied (at inlet 114) by hydrogen from a hydrogen-storage reservoir **202**, and (at inlet 116) with air from air pump **204**. The exhaust port 118 releases moist air and water droplets.

An atomizer **220** includes a resonant piezoelectric transducer. The transducer is driven at an ultrasonic frequency, e.g. 100 KHz, which atomizes water droplets. Thus any liquid-phase water in the gas flow exiting the atomizer 220 will be in the form of very small droplets.

A heat exchanger **230B** preferably follows the atomizer 220. This heat exchanger is coupled to the portable computer's CPU by a heat pipe, so it imparts a thermal rise to the gas flow exiting the atomizer. This helps to prevent condensation in or near the computer.

Alternatively a heat exchanger **230A** can be located before the atomizer, instead of or in addition to the following heat exchanger 230B. Here too the primary purpose is to prevent condensation. However, a side benefit is that a small amount of extra cooling for the computer can be obtained.

The flow of moist air is finally discharged through an external

exhaust port 240.

Figure 3 shows a fuel cell and its water discharge path in a second class of embodiments. In this class of embodiments the fuel cell 210 is followed by a separator **215** which extracts liquid water from the gas flow. (Alternatively, the separator 215 can be integrated into the fuel cell 210, so that liquid water is produced at a separate outlet of the fuel cell 210.) The small flow of liquid water is then fed directly to an atomizer **220'**, which atomizes and expels the water. The gas flow is simply exhausted directly through an external port 240.

Figure 4 shows a portable computer including a power converter **800** to operate from AC power, when available, and from fuel cell **802**. The power converter is connected, through a full-wave bridge rectifier FWR, to draw power from AC mains. The fuel cell 802 (or the converter 800), connected through a voltage regulator **804**, is able to power the complete portable computer system, which includes. in this example:

user input devices (*e.g.* keyboard **806** and mouse **808**);

at least one microprocessor **810** which is operatively connected to receive inputs from said input device, through an interface manager chip **811** (which also provides an interface to the various ports);

a memory (*e.g.* flash memory **812** and RAM **816**), which is accessible by the microprocessor;

a data output device (*e.g.* display **820** and display driver card **822**) which is connected to output data generated by microprocessor; and

a magnetic disk drive **830** which is read-write accessible, through an interface unit **831**, by the microprocessor.

Optionally, of course, many other components can be included, and this configuration is not definitive by any means.

According to a disclosed class of innovative embodiments, there is provided: A portable electronic system, comprising: electronic operating circuits which perform one or more functions; a fuel cell operatively connected to provide power to said operating circuits; and an ultrasonic atomizer which uses ultrasonic energy to atomize any liquid water produced by said fuel cell.

According to another disclosed class of innovative embodiments, there is provided: A computer system, comprising: a user input device; a microprocessor operatively connected to detect inputs from said input device; memory which is connected to be read/write accessible by said microprocessor; a video controller connected to said microprocessor; a display operatively connected to display data generated by said video controller at a first refresh rate; a fuel cell;

a power supply connected to provide power from said fuel cell to said microprocessor, said memory, and said display; and an ultrasonic atomizer which uses ultrasonic energy to atomize any liquid water produced by said fuel cell.

According to another disclosed class of innovative embodiments, there is provided: A method for operating a fuel cell, comprising the steps of: (a.) supplying an oxidant and a fuel which contains hydrogen to a dry-electrolyte membrane; (b.) allowing an electrochemical reaction to occur at said membrane in which hydrogen is oxidized to form water; and (c.) atomizing any water condensate from the cell by applying ultrasonic energy thereto, and expelling atomized water into the ambient air.

Modifications and Variations

As will be recognized by those skilled in the art, the innovative concepts described in the present application can be modified and varied over a tremendous range of applications, and accordingly the scope of patented subject matter is not limited by any of the specific exemplary teachings given.

Optionally a reservoir can be used to buffer the flow of water, in combination with atomization, as described above, to get rid of it.

The disclosed inventions can be applied to a wide variety of dry portable fuel cells. For example, the disclosed inventions can also be applied to fuel cell technologies which use a solid-oxide transport medium.